Projection electron microscopic image simulation for EUV mask pattern inspection

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Summary

We are developing a novel projection electron microscope (PEM) technique for detecting less than 18 nm in size defects on hp 16 nm EUV mask. In order to predict the optimal conditions for inspection, we are also developing an advanced simulation technique taking into account imaging electron optics (EO).

- **Designed imaging EO data can be imported to the simulator "CHARIOT™" ,improved by Abeam Technologies inc..**
- **Electron trajectories and focused images can be simulated as the imaging EO designed.**

Motivation

Design of imaging EO determines the quality of PEM image, besides, the characteristics of EUV mask PEM image depends on the geometry, the materials and the charging of the mask.

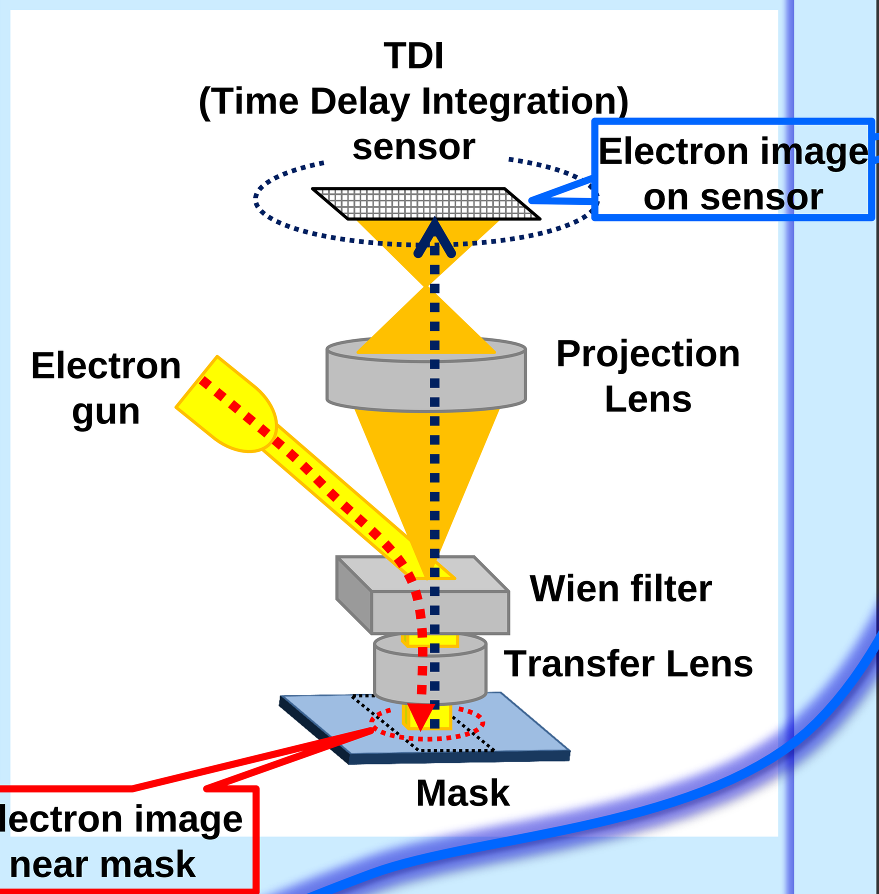
By tracing the electron trajectories, we can optimize the parameter such as landing energy, current density and imaging EO parameter. Therefore, we modified the CHARIOT software to import electromagnetic lens configuration.

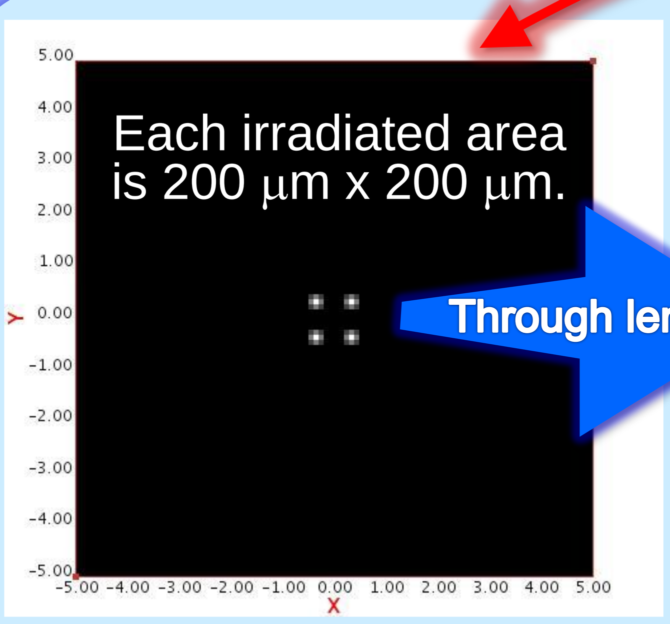
Advantage of taking into account imaging EO

Simulation	Near mask	On sensor
Aberration	no	yes
aperture size	no	yes
Transmittance	no	yes
energy filtering effect	yes by adjusting energy range of detector	yes
SE_{III}	no	yes but not yet in this presentation

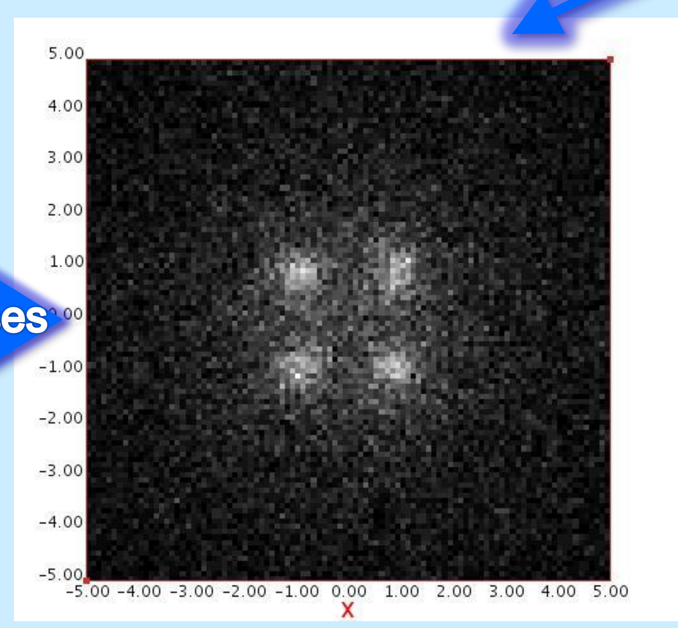
SE_{III}: produced by high energy BSE which strike pole pieces and other solid objects near the specimen.

Schematic illustration of Projection Electron Microscope (PEM)

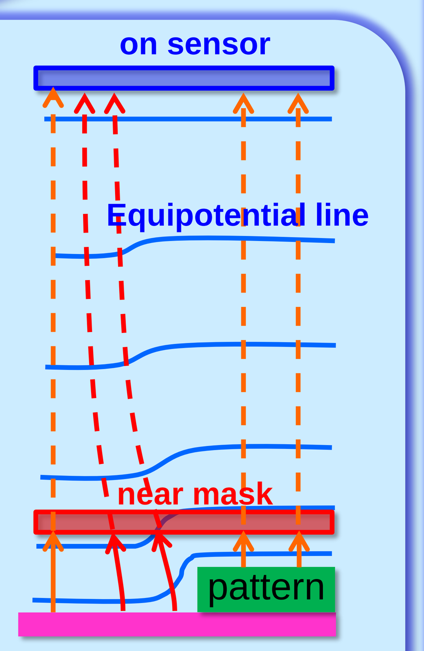




Near field image
1nm height
above the sample

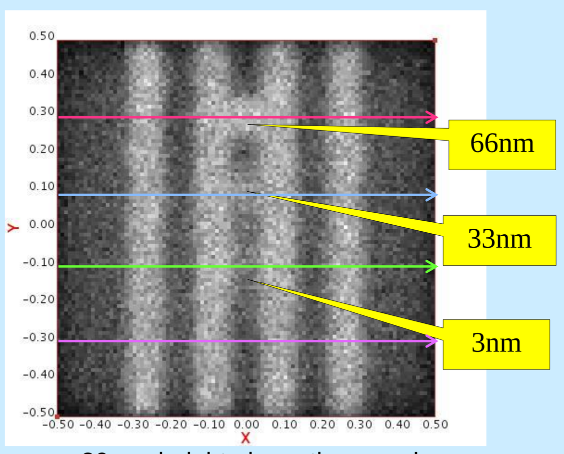


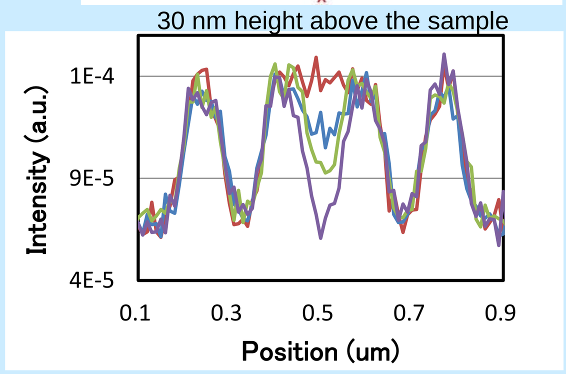
Focused image
~200 mm height
above the sample.



Schematic illustration of affected electron trajectories by potential distribution

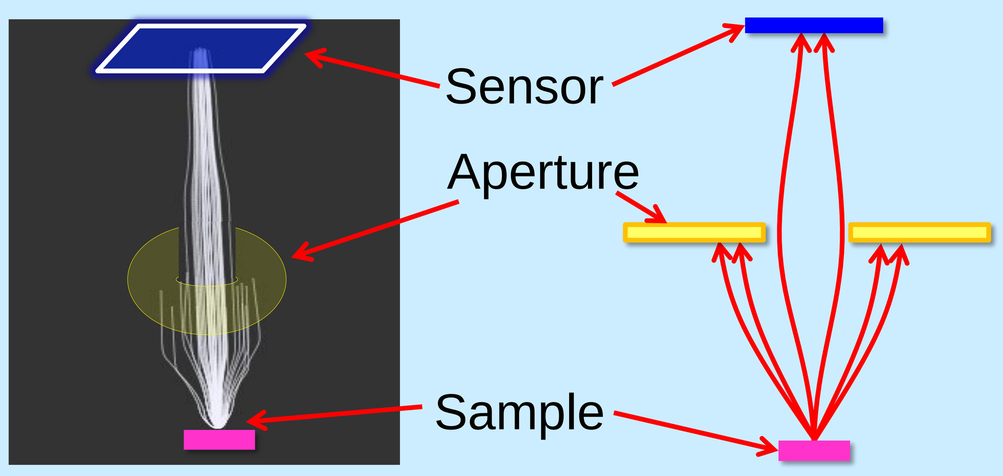
We can examine the influence of aberration, noise and etc. on the image. Also, the electron trajectories are affected by the potential distribution generated by mask geometry, charging effect and external electric field. These phenomena can be investigated by using this technique.





Identification of residual-type defects

We have already investigated the simulated **near field image** of residual-type defects with various thicknesses[1-2]. The focused image is now being examined.



Electron trajectories can be cut by aperture stop

We can examine the influence of the size and shape of an aperture and the transmittance on the image. Undesirable electrons, which leads to the aberration and low MTF of the image, can be eliminated by the aperture.

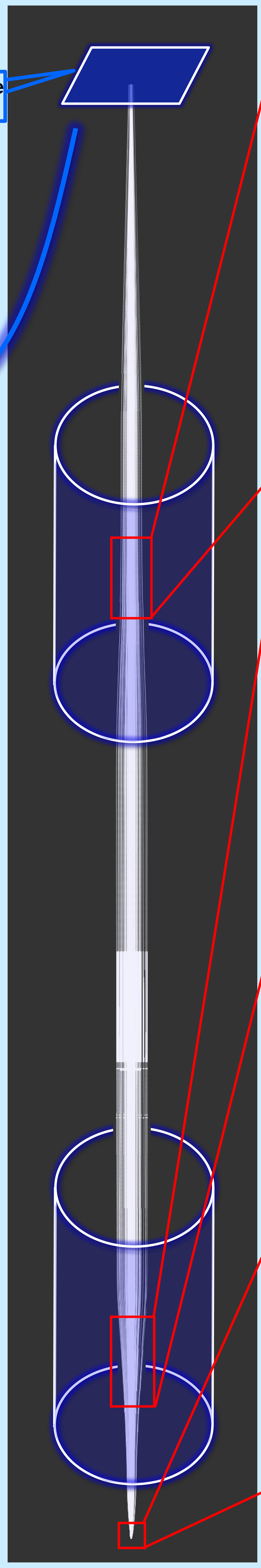
Simulation tool

CHARIOT Monte Carlo software (Abeam Technologies, Inc.) with 72 cores was installed in an all-in-one server computer, Proliant DL 980 G2 (Hewlett-Packard) with 80 cores.

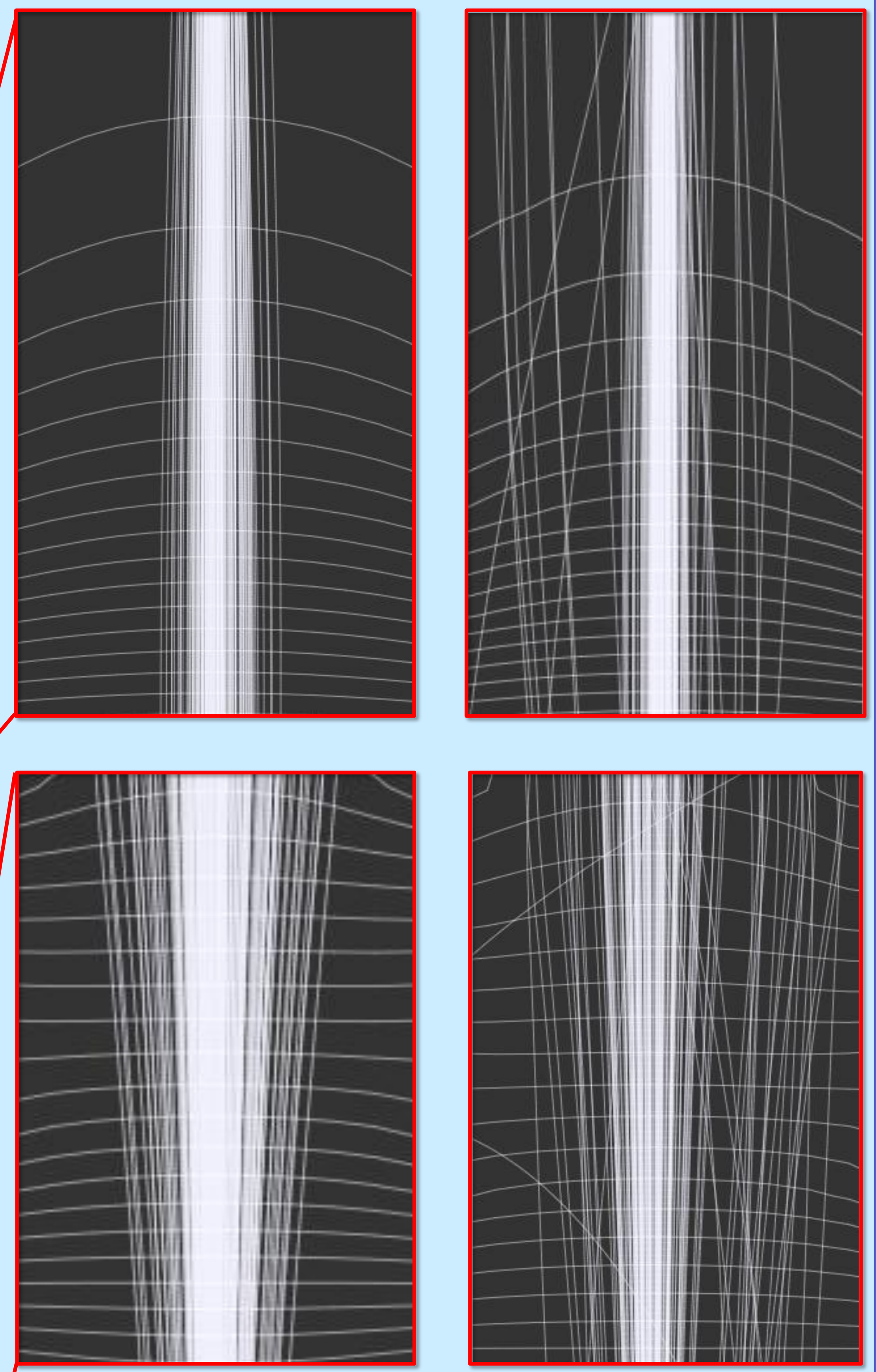
Electron trajectories through the imaging EO without aperture

Landing energy < 50 eV

Landing energy 1000 eV



Electron trajectories generated from the sample

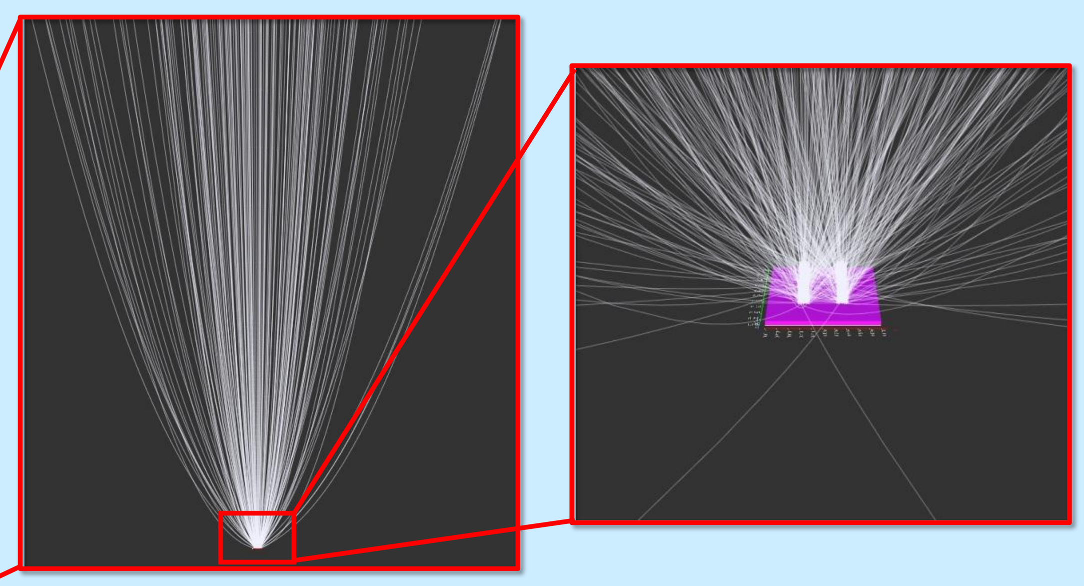


Magnified electron trajectory with visualized equipotential lines

Only electrons with < 50 eV can be focused on an imaging plane by the EO design.

In the case of 1000 eV, electrons with > 50 eV such as BSE do not focus. Such electrons can eliminate by an aperture.

On the other hand, we can obtain the BSE image through the imaging EO depending on the EO design.



Electron trajectories near the sample

Sample size is 1µm x 1µm.

Electrons are accelerated and focused on the imaging plane by passing through the imaging EO.

Future work

Improvement of the calculation accuracy and the simulation speed.
Implementation of taking into account SE_{III}.

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Reference:
1) S. Iida et al. J. Vac. Sci. Technol. B 30, 06F503 (2012)
2) T. Amano et al. J. Vac. Sci. Technol. B 30, 06F501 (2012)

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